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16. ABSTRACT The paper describes pilot plant experience with techniques with a potential for improving the performance of electrostatic precipitators (ESPs) by using a novel rapping reentrainment collector and flexible steel cable (in place of solid large-diameter discharge electrodes) for both new and retrofit applications. Rapping reentrainment is a major source of particulate emissions from high efficiency ESPs (in some cases over 50% of the particulate mass emitted from the ESP is from rapping reentrainment). Significant improvement in ESP technology could thus be achieved if emissions from rapping reentrainment were reduced. Large diameter discharge electrodes about 9 mm in diameter allow attainment of higher electric fields with useful corona currents than do conventional electrodes (typically about 3 mm in diameter). A novel rapping reentrainment collector was evaluated at small pilot plant scale. The collector consisted of a small precharger followed by a very short collector zone. The precharger used was the cooled electrode precharger developed by Denver Research Institute under EPA sponsorship. The precharger puts a very high charge on the reentrained particles. The particles are then collected with high efficiency in the short collector zone. The overall mass collection efficiency of the reentrainment collector was about 85%.

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Electrostatic Precipitators	Stationary Sources	13I
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Dust	Rapping Reentrainment	11G
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PILOT SCALE EXPERIMENTS TO IMPROVE PERFORMANCE OF ELECTROSTATIC PRECIPITATORS

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ABSTRACT. This paper describes pilot plant experiences with techniques having the potential for improving performance of electrostatic precipitators (ESPs) by the use of a novel rapping reentrainment collector and the use of flexible steel cable in place of solid large diameter discharge electrodes for both new and retrofit applications.

Rapping reentrainment is one of the major sources of particulate emissions from high efficiency ESPs. In some cases over 50% of the particulate mass emitted from the ESP is due to rapping reentrainment. Significant improvements in ESP technology could thus be achieved if emissions due to rapping reentrainment were reduced.

Large diameter discharge electrodes of about 9 mm in diameter allow attainment of higher electric fields with useful corona currents than do conventional electrodes, which are typically about 3 mm in diameter. In weighted wire applications it is difficult to straighten the electrodes and to maintain alignment with solid large diameter wires. Flexible steel cable of the same diameter was easily straightened with relatively light weights.

A novel rapping reentrainment collector was evaluated at small pilot plant scale. The collector consists of a small precharger followed by a very short collector zone. The precharger used in these experiments was the cooled electrode precharger developed by Denver Research Institute under EPA sponsorship. The precharger puts a very high charge on the reentrained particles. The particles are then collected with high efficiency in the short collector zone. The overall mass collection efficiency of the reentrainment collector was about 85%. The collection efficiency for 5 μm diameter particles was about 80%. Measurements of actual rapping reentrainment emissions show a mass mean diameter of about 6 μm and a geometric standard deviation of 2.5. These results indicate that the rapping reentrainment collector has potential for significantly reducing the particulate emissions from existing ESPs.

Flexible steel cables, 3.18 and 9.54 mm in diameter, were compared with solid corona discharge wires of the same size. Under clean conditions the smooth solid wires operated at higher voltages than the less smooth flexible cables. When dirtied, by operation with flyash, there was no discernible difference in voltage/current characteristics for either size wire.

INTRODUCTION

It often becomes necessary to upgrade the performance of an electrostatic precipitator (ESP) to achieve compliance with particulate air pollution regulations. In those situations the ESP is first restored to its original mechanical specifications by replacing broken corona discharge electrodes, repairing warped collector plates and misalignment, tuning up rapping cycles, etc. Once the ESP is put back into good mechanical condition, additional measures may have to be instituted to improve performance still further.

This paper presents two retrofit options that can increase the performance of a mechanically sound ESP. The first is a device to suppress both rapping and

non-rapping reentrainment. The second is a simplified approach for increasing the diameter of a weighted corona discharge electrode wire as a means for increasing the electric field.

The first option is a device to suppress reentrainment of the collected particulate matter that occurs in two forms--rapping and non-rapping. Rapping results in reentrainment into the gas stream of some of the particulate matter dislodged from the collector plates during their periodic cleanings. In addition, wind erosion from the surface of the dust layer also causes the particulate matter to return to the gas stream. The two types of reentrainment emissions are particularly significant when they occur in the last electrical section of an ESP and are emitted with the exiting gas stream. The residual particulate emissions in a well performing, high efficiency ESP are usually due to reentrainment from the last electrical section.[1]

To capture particulate matter that is reentrained, a device has been tested that can be fitted into the space that is usually available downstream of the last electrical section in the ESP prior to the transition section. The device consists of a precharger followed by a single-wire collector. The precharger is of the cold pipe type that is used in the multistage ESP.[2] The single-wire collector would use conventional ESP technology. The cooling of the collector electrode of the precharger lowers the resistivity of the particulate matter collected there. The lowered resistivity minimizes back-ionization and allows high corona currents necessary for rapid charging. For lower resistivity particulate matter, cooling of the collector pipes may not be necessary. In addition, if there is sufficient room, more than one wire can be used in the collector for still further performance improvement in the reentrainment separation.

The concept was suggested by pilot plant work that had been done previously on the multistage ESP technology. It was seen that more particulate matter would collect under the first wire in the first electrical section than under any of the other wires. This was not surprising. In a two-stage ESP, unlike a conventional one in which uncharged particles approach the first wire, the particles from the precharger contain a high level of charge, and the migration velocity and collection are consequently much higher.

The second option is a simplified means for increasing the diameter of the corona discharge electrode when the weighted wire is used. The replacement of a smaller diameter corona discharge electrode with one of larger diameter under many ESP conditions improves performance. Depending on the diameter of the new corona discharge electrode wire, it is possible to obtain significantly higher electric fields while still having sufficient corona current for particle charging and for holding the collected particulate matter onto the collector plate [3,4].

In a weighted-wire ESP the corona discharge electrodes are suspended from an electrode frame and are caused to hang straight by a weight placed at the bottom of each as in Figure 1. Unfortunately, replacing a small diameter weighted corona discharge electrode wire with one of larger diameter would generally require the use of a larger weight to attain straightness and to maintain alignment. Replacing the weights with heavier ones would add to the cost of the retrofit and may, in addition, require reinforcement of the supporting structure.

Flexible steel cable rather than solid wire electrodes would hang straight with relatively small weight. However, it would be necessary to determine the electrical characteristics of the flexible cable as compared to the solid material to ensure that similar performance would be achieved in an ESP.

EXPERIMENTAL WORK - GENERAL

The experimental work on the reentrainment separator and the flexible wire corona discharge electrodes was done on the pilot ESP of the Air and Energy Environmental Research Laboratory of EPA at Research Triangle Park, NC. The EPA pilot ESP has been described previously.[5] In summary, the pilot ESP consists of four independently energized, single-lane sections in series. The collector plates are each 1.22 m square, and the plate-to-plate spacing is adjustable from 0.13 to 0.40 m. An electrode frame is used to hold the corona discharge electrodes, which can be varied in size and type. The particulate matter is redispersed into the gas stream which can range in temperature between ambient and about 350°C. The nominal gas flow is 28.3 actual m^3/min, which can be adjusted up and down.

For both the reentrainment separator and flexible steel cable corona discharge electrode experiments, the pilot ESP was operated at a temperature of 149°C and a moisture level of 5%. The particulate matter was a flyash from a pulverized-coal-fired boiler that was redispersed into the gas stream by an array of pneumatically activated sand blast guns to provide a particulate loading of about 4.6 g/m^3. The resistivity of the flyash was low enough to minimize the possibility of back-ionization.

EXPERIMENTAL WORK - REENTRAINMENT COLLECTOR

For the reentrainment collector experiment the pilot ESP was configured with the inlet electrical section as shown in Figure 2. The section consisted of the cold pipe precharger upstream of the collector; a single 9.54 mm corona discharge electrode was placed in the collector section as shown to simulate the single-wire collector of the reentrainment collector.

Calibrated impactors were used to determine particle gas loading as a function of particle diameter both upstream and downstream of the reentrainment collector.

Four test runs were made. The voltage and current ranged from 45 to 47 kV and 0.47 to 0.60 mA, respectively. Collector voltage and current ranged from 44 to 50 kV and 0.60 to 0.90 mA, respectively.

The penetration as a function of particle diameter was calculated using a spline fit data reduction program. The average of all runs is shown in Figure 3. Note that the penetration as a function of particle diameter in the critical range for reentrainment, which is 2 to 10 μm [1], is about 20%, corresponding to 80% efficiency.

EXPERIMENTAL WORK - FLEXIBLE STEEL CABLE

One section of the pilot ESP was operated in the weighted wire configuration. The corona discharge electrodes were of four types--solid wire and stranded flexible cable each of 3.18 and 9.54 mm diameter. The flexible cable consisted of 7 strands each of 19 galvanized wires. The material was used as received from the vendor. No attempt was made to clean either the cable or solid electrode material or otherwise improve the surface conditions. Previously a non-galvanized cable had been tried. However, as obtained from the vendor, it was heavily coated with a lubricant which combined with the flyash to form a difficult-to-remove mixture. The electrodes were located on 230 mm centers. Plate-to-plate spacing was also 230 mm.

For each test the discharge electrodes and collector plates were cleaned, and the current vs. voltage conditions were measured. The flyash injector would then be started and, after 16 hours, the electrical conditions would be measured for the now dirty electrodes.

The results of the tests for the 3.18 and 9.54 mm solid and flexible corona discharge electrodes are shown in Figures 4 and 5, respectively. As is expected the clean condition electrode voltages were higher than they were for the dirty electrode voltages. There were differences between the 9.54 mm solid and stranded cable corona discharge electrodes, under clean conditions; there were no significant differences for the 3.18 mm electrodes. The most likely reason for the difference under clean electrode conditions was surface roughness. The voltage/current characteristics were generally consistent with the expected electrical conditions for the experimental conditions.

The most interesting observation is that, once the electrodes become dirty, there do not appear to be any significant electrical differences between the solid and stranded cable corona discharge electrodes.

CONCLUSIONS

A reentrainment collector has been proposed and tested. It consists of a cold pipe precharger plus a single-wire collector for the charged particles. In pilot scale tests the device collected about 80% of the particles in the 2 to 10 μm range.

The reentrainment collector itself would also suffer from reentrainment. The magnitude of the reentrainment collector's losses from reentrainment cannot be calculated with certainty but can only be estimated. If it is assumed that, at the lower limit, the reentrainment is no less than that of a normal collector stage, which is about 10%, the net efficiency of the reentrainment collector would be about 72%. If it is assumed that, at the upper limit, the reentrainment collector has a reentrainment loss of 20%, then the net efficiency of the collector would be about 64%. This bounded range is realistic because both the precharger and collector stages will capture particulate matter, and any material reentrained from the precharger would be collected by the next stage. Thus it is reasonable to assume that the reentrainment collector could reduce particulate emissions by at least 50%. A 50% reduction in emissions is often sufficient to bring an ESP into compliance for particulates.

The length required by a practical reentrainment collector having a plate-to-plate spacing of 230 mm, as determined from Figure 2, would be about 320 mm. This amount of extra room would usually be available after the last electrical section. If additional space is available the use of two electrodes in the collector should be considered for additional reentrainment collection. For other plate-to-plate spacings the amount of space that would be required for installation of the reentrainment collector would have to be adjusted.

It has been shown that corona discharge electrodes made from flexible steel cable behave similarly to electrodes made from smooth wire once they become coated with particulate matter. What is not known is how full-length flexible cable electrodes will behave when they are mechanically rapped for cleaning. Limited experience with the rapping of the short electrodes, that were evaluated in the pilot plant, showed very little difference in rapping behavior. Only experience with the larger electrodes in full size ESPs will answer this question. The ease and simplicity that would be involved in installing flexible steel corona discharge electrodes in a full size ESP suggests that it would be a worthwhile approach for increasing the diameter of corona discharge electrodes for improved performance of an ESP.

REFERENCES

1. J. P. Gooch and G. H. Marchant, Jr., Electrostatic Precipitator Rapping Reentrainment and Computer Model Studies, Volume 3, EPRI FP-792, Palo Alto, CA, August 1978.

2. M. Durham, G. A. Rinard, and D. E. Rugg, Pilot Plant Evaluation of the Cooled Electrode Precharger as an ESP Retrofit Device, Presented at Sixth Symposium on the Transfer and Utilization of Particulate Control Technology, New Orleans, LA, February 25-28, 1986.

3. P. Vann Bush, D. H. Pontius, and L. E. Sparks, Performance of Large-Diameter Wires as Discharge Electrodes in Electrostatic Precipitators, In: Proceedings: Fifth Symposium on the Transfer and Utilization of Particulate Control Technology, Volume 2, EPA-600/9-86-008b (NTIS PB86-167160), February 1986.

4. K. J. McLean and L. E. Sparks, Electrical Characteristics of Large-Diameter Discharge Electrodes in Electrostatic Precipitators, In: Proceedings: Fifth Symposium on the Transfer and Utilization of Particulate Control Technology, Volume 2, EPA-600/9-86-008b (NTIS PB86-167160), February 1986.

5. P. A. Lawless, B. E. Daniel, and G. H. Ramsey, Characterization of the EPA/IERL-RTP Pilot-Scale Precipitator, EPA-600/7-79-052 (NTIS PB292820), February 1979.

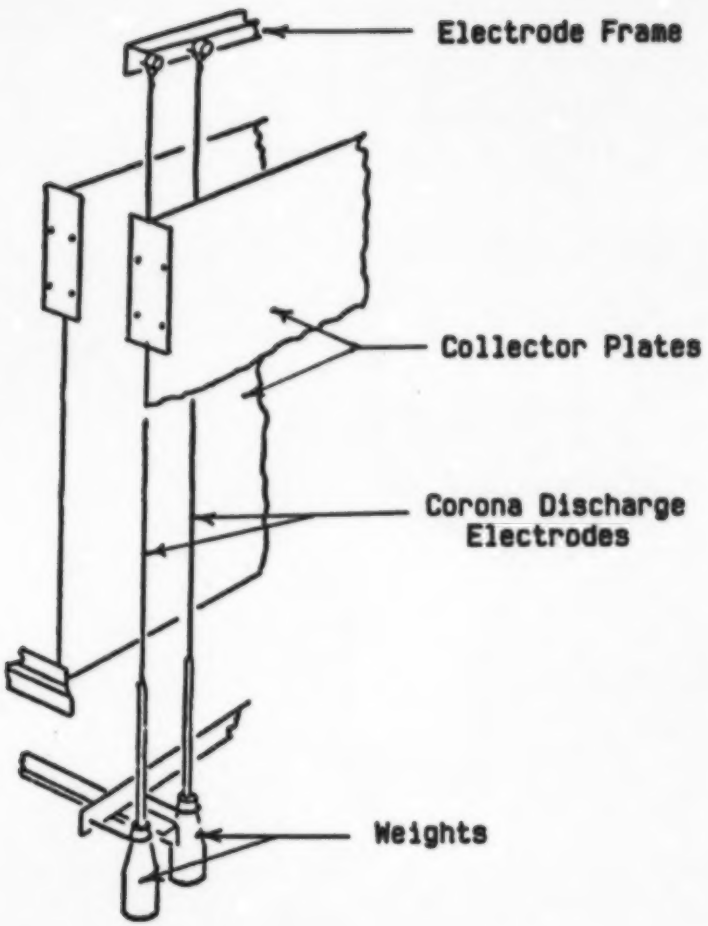

Figure 1. Weighted wire corona electrodes.

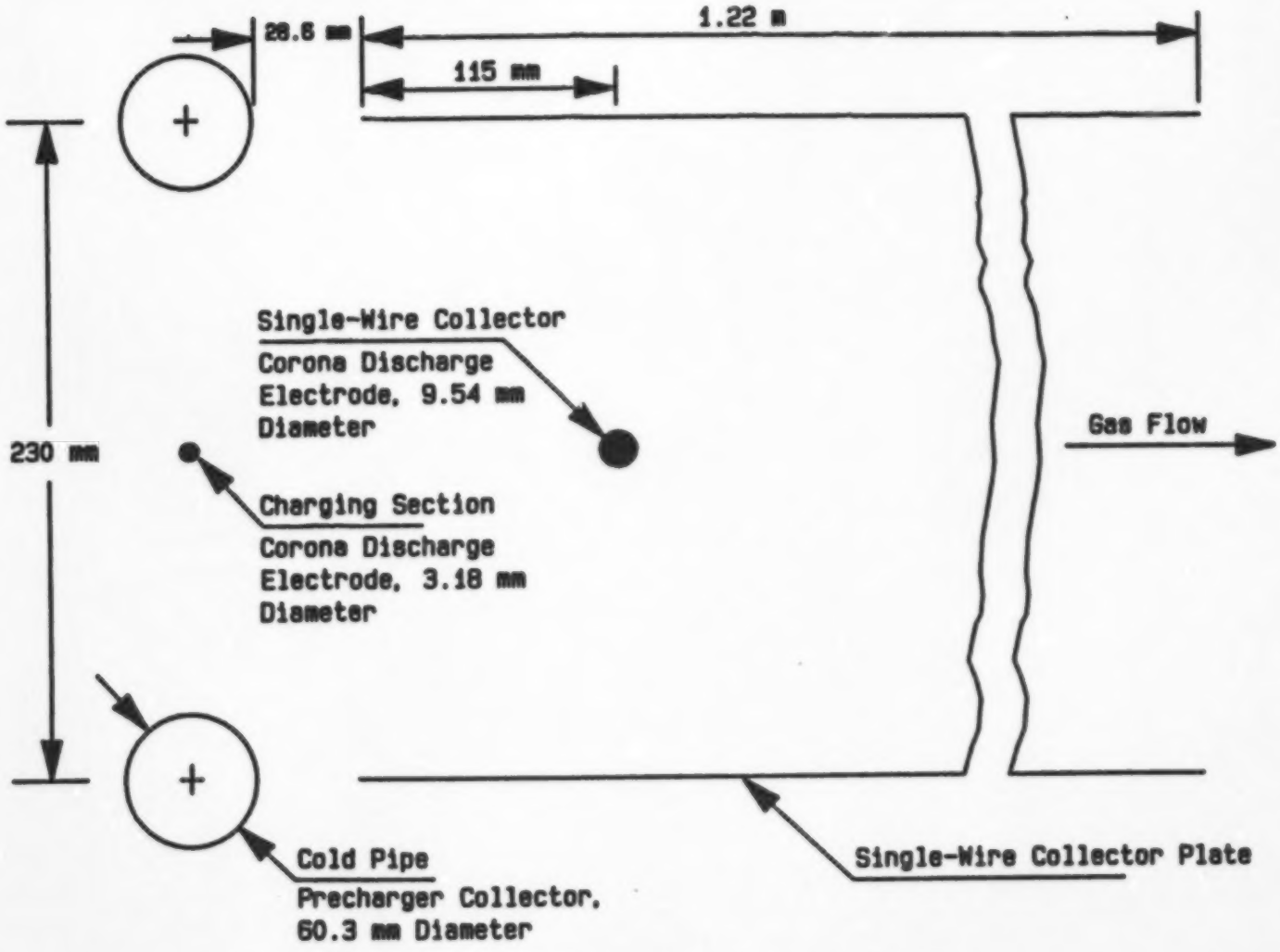

Figure 2. Setup of cold pipe precharger and single-wire collector for reentrainment collector experiment.

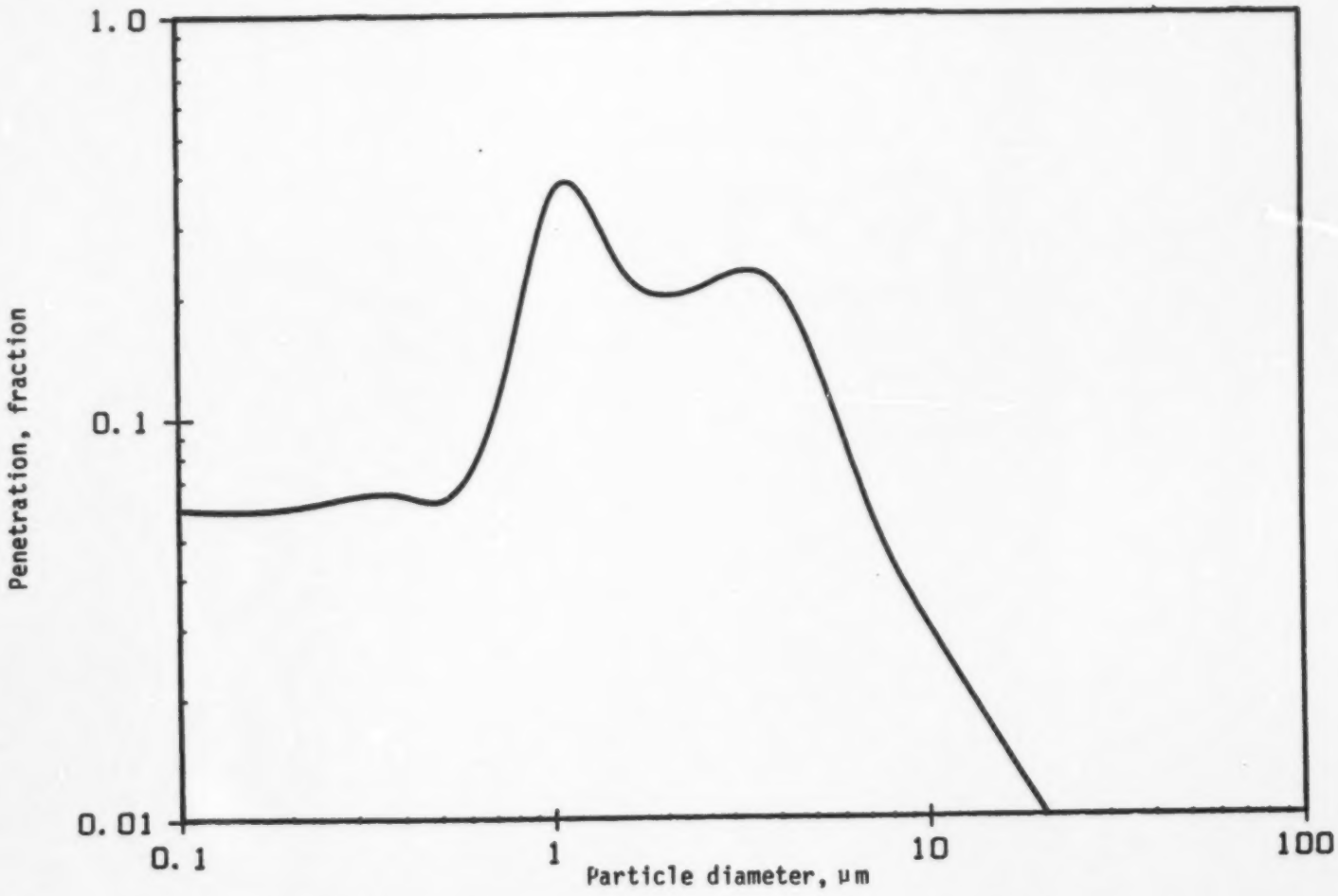

Figure 3. Penetration vs. particle diameter for reentrainment collector.

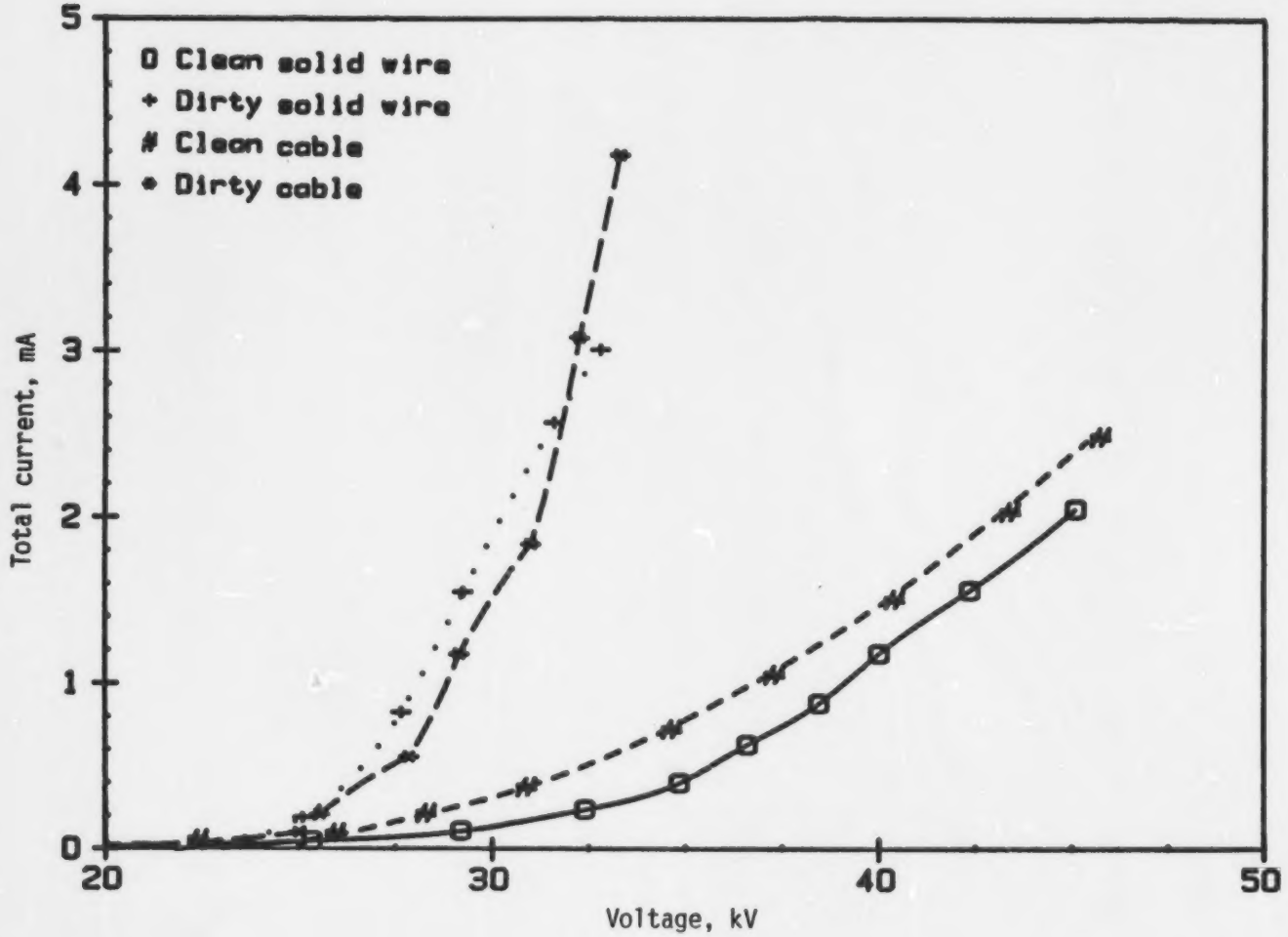

Figure 4. Voltage/current for 3.18 mm solid and flexible corona discharge electrodes.

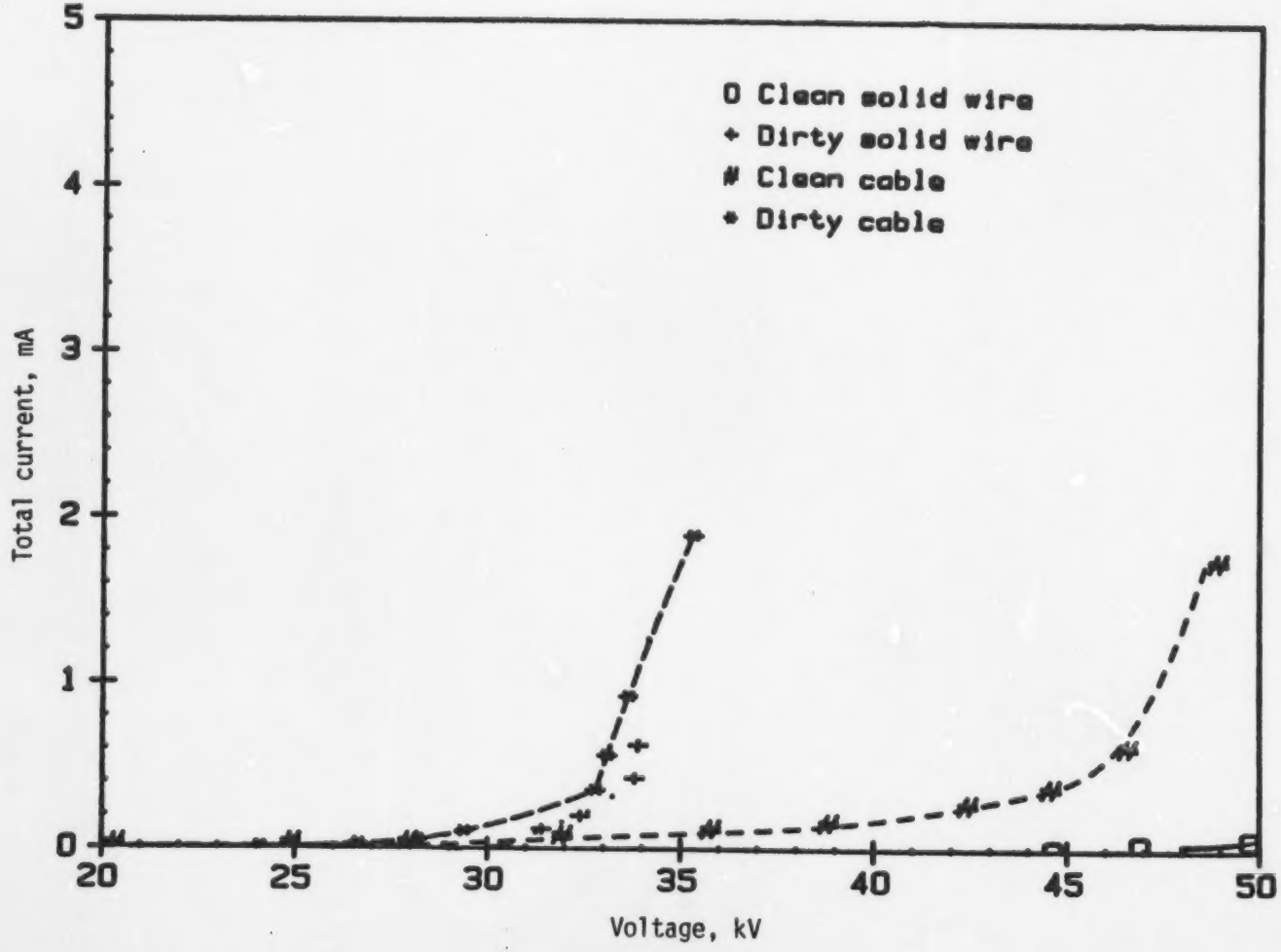

Figure 5. Voltage/current curves for 9.54 mm solid and flexible corona discharge electrodes.